ADAPTABLE, DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT) FOR FUTURE MARS MISSIONS

IPPW10 Future Mars II Session

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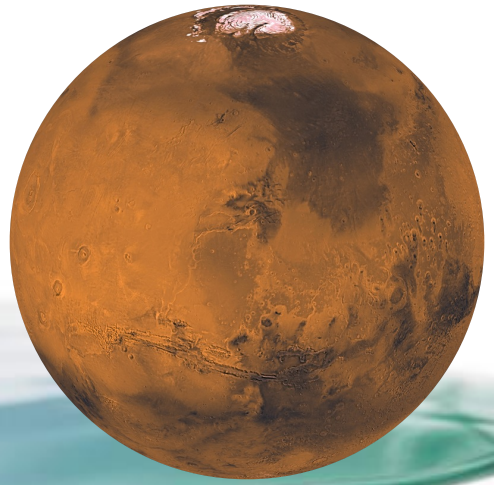

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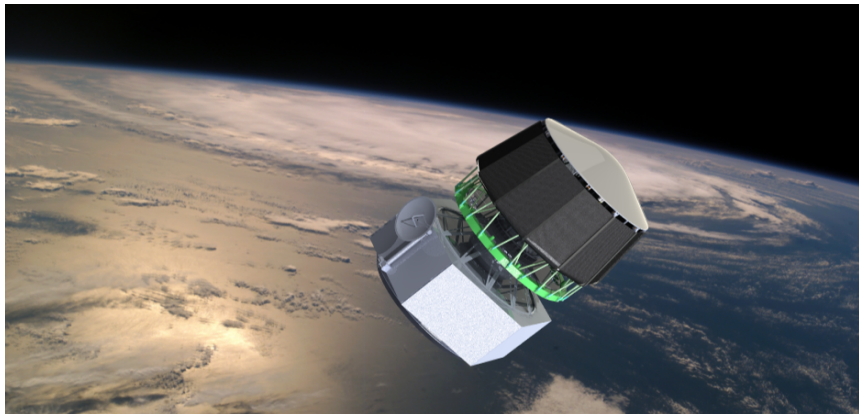
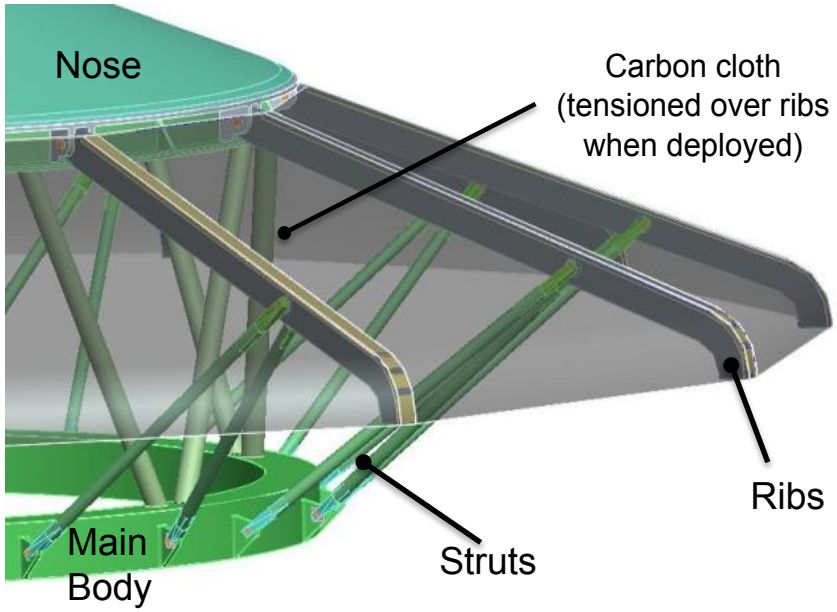
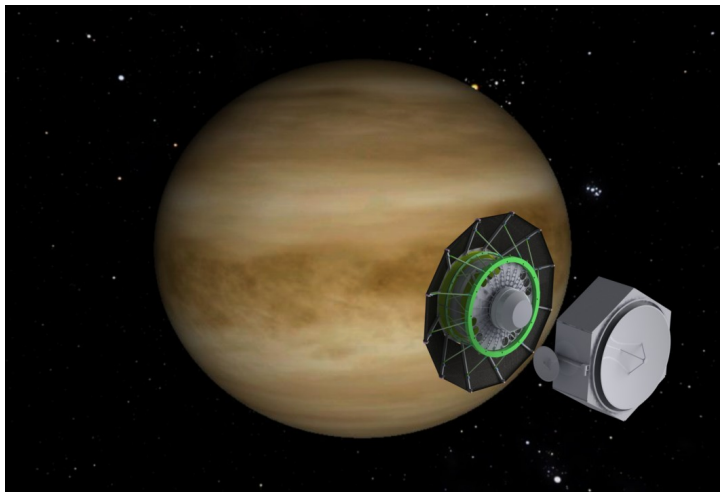
ADEPT (Adaptable, Deployable, Entry and Placement Technology)

- *Low ballistic coefficient entry architecture ($m/CdA < 50\ kg/m^2$)*
- *Consists of a series of ribs and struts, connected with flexible 3D woven carbon fabric skin*
  - *Stowed at launch to fit within launch vehicle shroud*
- *Deployed near planet arrival and functions as a semi-rigid aeroshell system to perform entry descent landing (EDL) functions.*



Earth departure





Venus Arrival

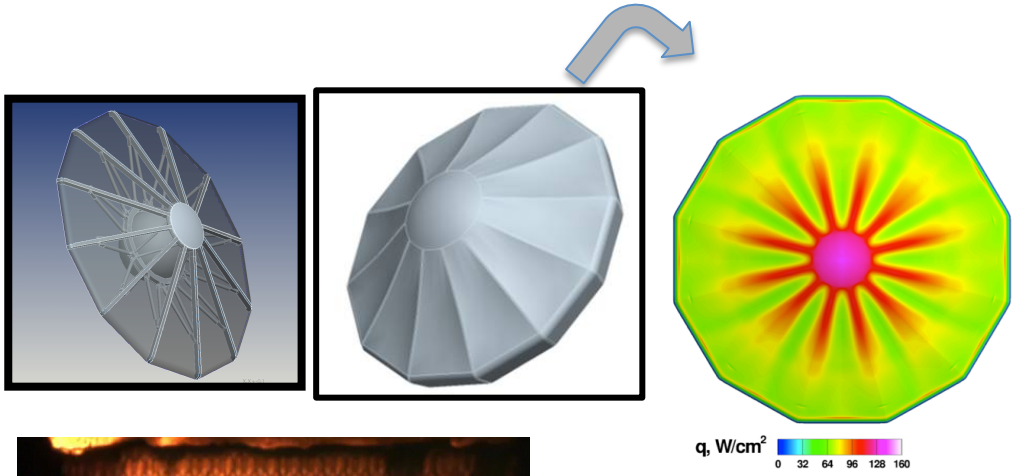
ADEPT Technology Maturation Project (FY12-13) Overview

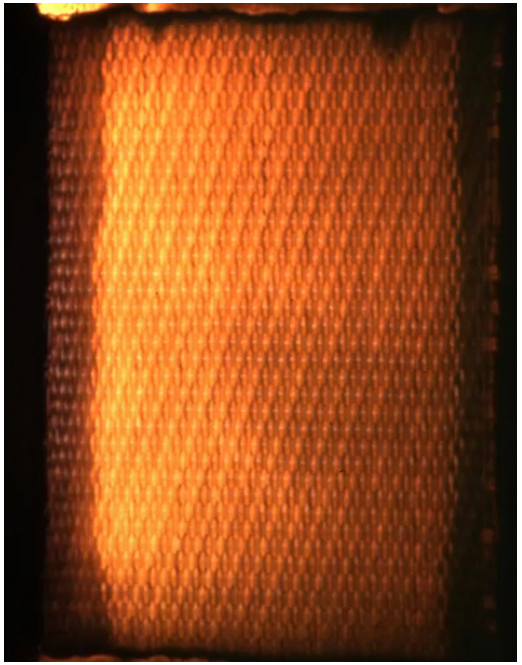
ADEPT is an STMD GCD Project started in FY12

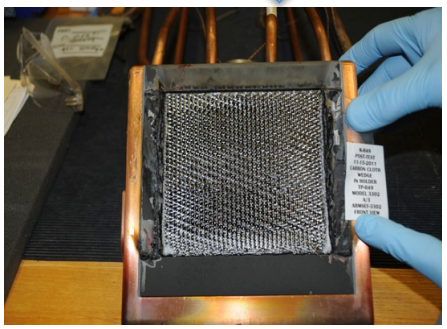
Project Deliverables

- **Characterize thermal and mechanical performance of 3D woven carbon fiber fabric**
  - Produce flight like woven fabric skin for ground test article and integrate with breadboard structural/ mechanical system
  - *Capable to 250W/cm^2*
- **Perform mission feasibility study to understand operational requirements/ parameters and sizing calculations**
- **Design, Fabricate and Test sub-scale ground test article (~2m diameter)**
  - Fabricate rib/strut/ring/nose structures using COTS type extruded shapes for breadboard structural support system
  - Design and procure COTS hinge/joint/deployment mechanisms to simulate behavior of ADEPT for ground testing

ADEPT was recently approved for Full Scale Demonstrator New Start Project in FY14







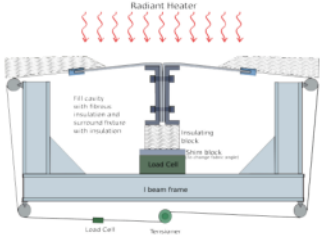
ADEPT Technology Development Challenges

Challenge Area	Description	Mitigation and Verification
Fabric Thermal Performance	Test at and above anticipated peak heating and heat load anticipated for Venus entry	Arc-jet test series in FY14 to establish performance bounds at and above expected heat rates and integrated heat loads
Fabric Interfaces	C-fabric to: 1) rib; 2) nose; 3) shoulder/ close-out	Arc-jet testing (Sprite-C) and radiant testing will establish performance and failure modes
Deployment	Deployment function and reliability testing on 2 m GTA and fullscale prototype	More relevant flight mission conditions can be replicated on ground for a range of off-nominal states
Thermostructural	Understand thermal design issues- materials selection and performance	Component level radiant tests will validate modeling tools to predict thermal and structural stress
Aerodynamic Stability	Blunt body entry vehicles in supersonic to transonic regime may be dynamically unstable	Ballistic Range Testing below Mach 3 and analysis will validate free-flight CFD codes
Integrated System	There is no end to end ground test, but the key system test is thermal vac deployment and vibe acoustic of full scale vehicle	Utilize thermal vac and vibracoustic test approaches at full scale with flight materials and relevant payload simulator
Fluid Structure Interaction	Flutter of cloth could lead to aerodynamic stability issues	Perform component level testing in relevant environment to validate FSI codes
Manufacturability	Establish manufacturing, assembly and integration at relevant scale	Relevant scale Venus aeroshell manufacturing & assembly processes will be demonstrated

BLAM Test Fixture

C-Fabric & Interface Thermal Performance

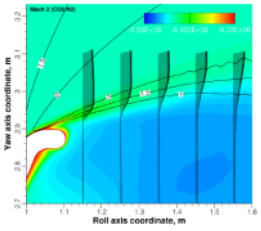
Radiant Test Fixture



Fabric/Rib Interface

Component Thermostructural Testing

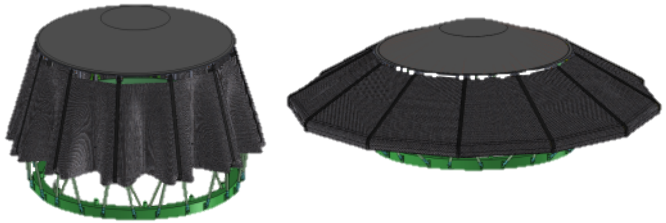
Mach contours on shoulder



FSI modeling for wind-tunnel model design

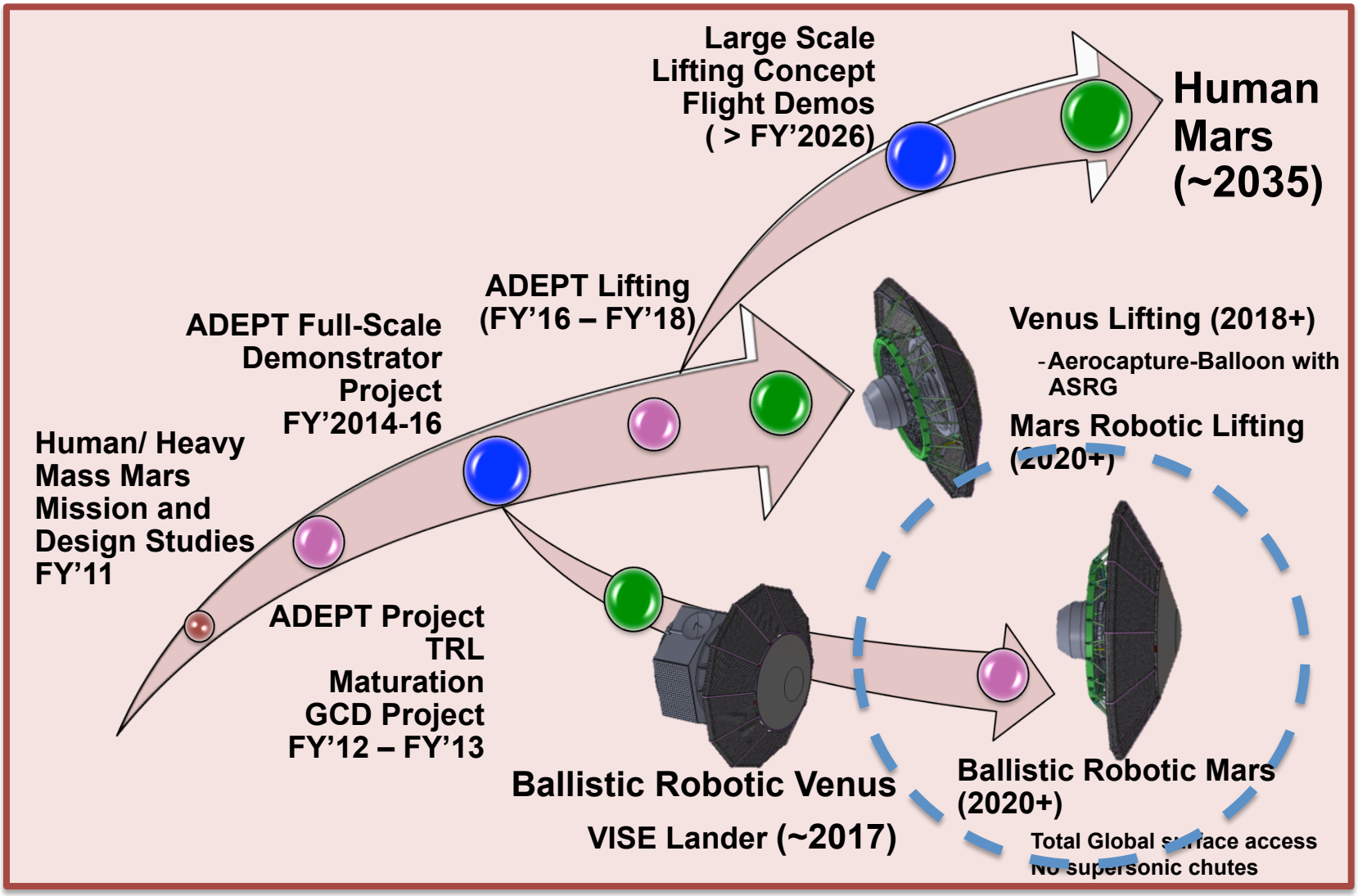
stowed

deployed



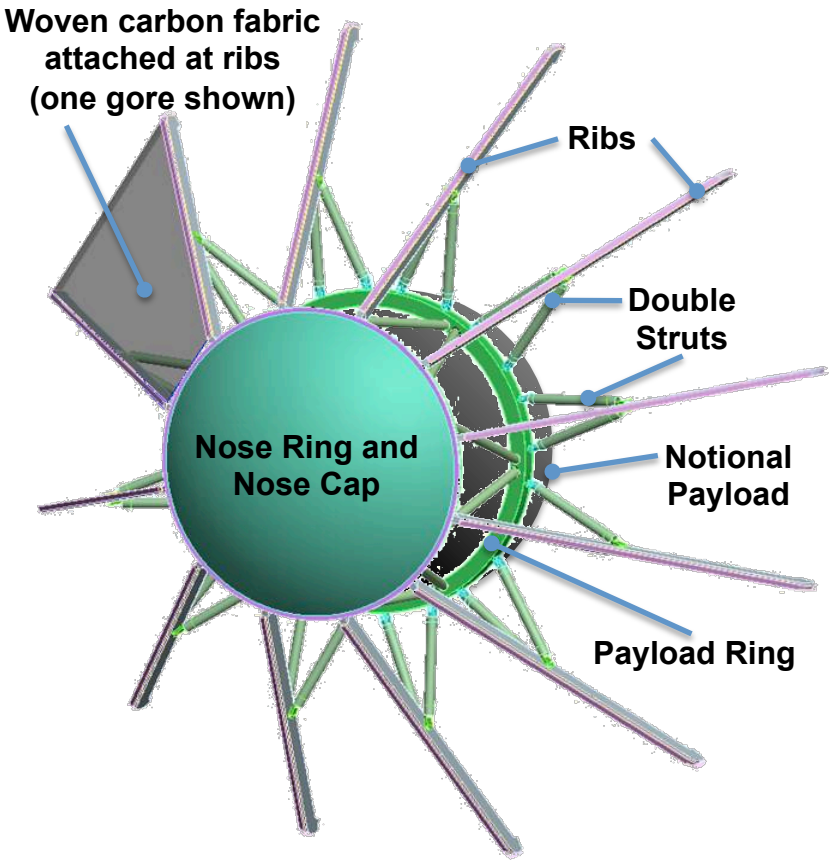
Deployment Testing

ADEPT Mission Infusion
Potential Mid-Term Mars Mission



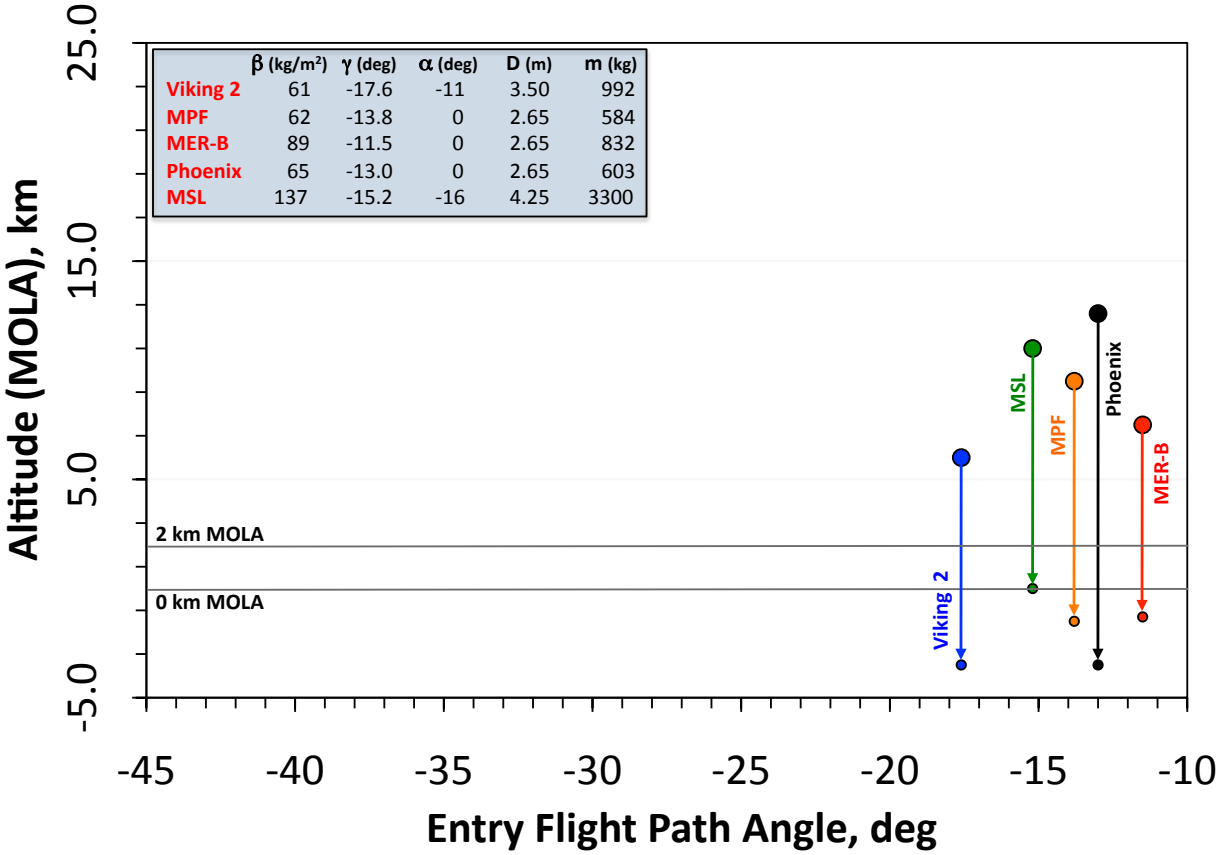
Initial Assessments of ADEPT for Future Mars Missions

Element	% of Entry Mass
ADEPT:	**46 %**
Primary Structure (main body, nose cap, lock ring, ribs & bearings, struts & end fittings, joint hardware, carbon cloth)	28 %
TPS (nose, ribs, aft cover)	4 %
Payload Backshell (also contains parachute)	2 %
Mechanisms and Separation (deployment system, stowed/deployed latches, separation ring and guide rails, backshell sep mechanisms, parachute system	12 %
Avionics and Power (avionics unit, harness, power unit)	1 %
Payload:	**54 %**



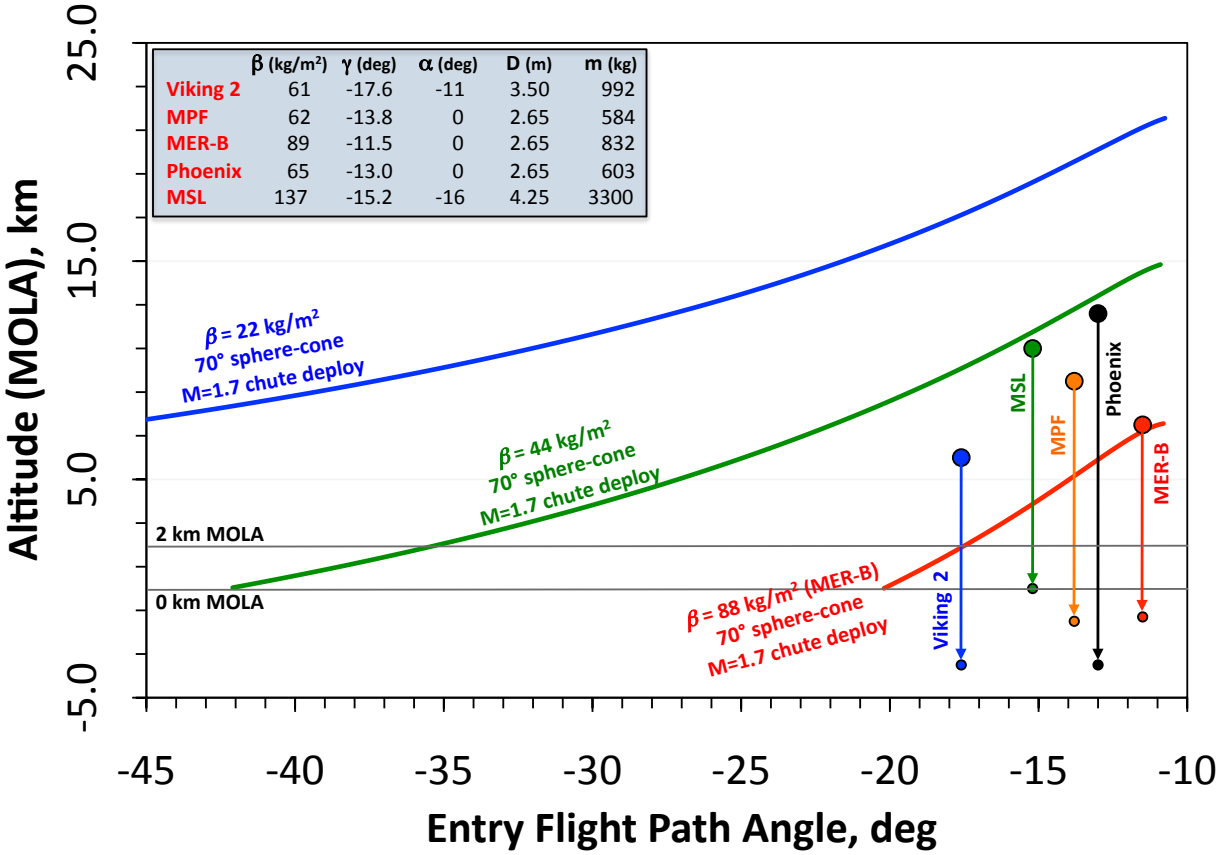
- ADEPT Conceptual Designs for 5-15m class mission applications
  - Identification of components and mass estimating relationships
  - Preliminary MELs have been generated to support mission studies based on Venus entry mission studies (conservative)

Mars Challenges with Current EDL Technology



- Existing EDL Technology
  - -Limits Landed Payload Mass (~ 1 mT)
  - -Requires use of Supersonic Parachutes
  - -Access to Mars Surface Limited by ~ 0 MOLA altitude limit

ADEPT Enables Global Mars Access



Decelerator Diameter, m

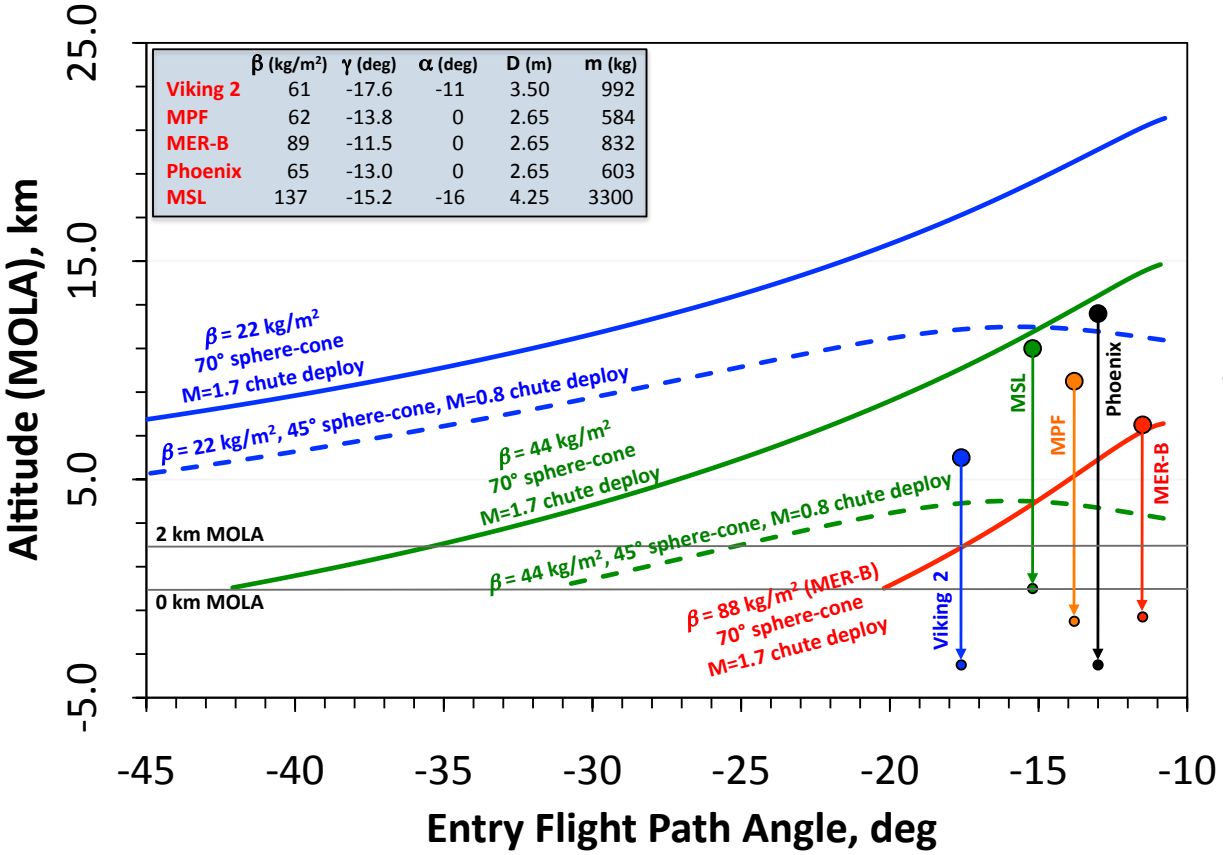
Entry mass kg	θ_c deg	β=22 kg/m²	β=44 kg/m²	β=88 kg/m²
1000	70	5.8	4.1	2.9
2500		9.2	**6.5**	4.6
4000		11.7	8.3	5.8
1000	45	7.4	5.2	3.7
2500		11.7	8.3	5.9
4000		14.8	10.5	7.4

Example:

70° sphere-cone ADEPT

Diameter	= 6.5 m
Entry Ballistic Coefficient	= 44 kg/m²
Entry mass	= 2500 kg
Aeroshell Mass	= ~ 870 kg
Descent/Payload	= ~1630 kg

ADEPT Enables Global Mars Access



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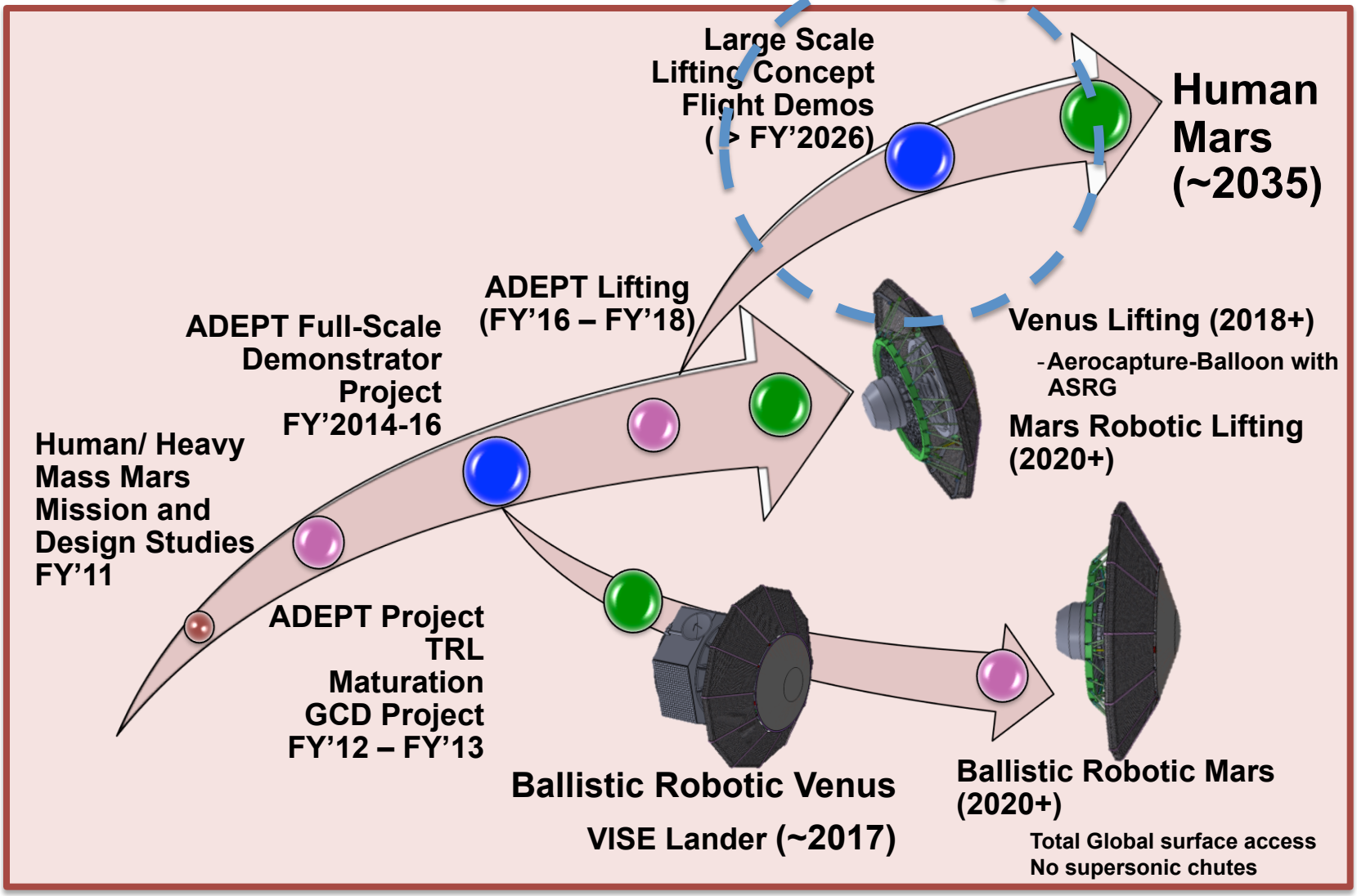
- Ballistic entry with ADEPT can eliminate risky EDL events for Robotic Mars
- High altitude deceleration results in benign aerothermal environment and g-load's
- ADEPT architecture allows steeper FPA reducing landing dispersion footprint
- ADEPT can enable subsonic parachute deployment at high altitudes
- With ADEPT, landing site elevations is not an issue – Access any site on Mars

ADEPT Technology Maturation and Mission Infusion Timeline

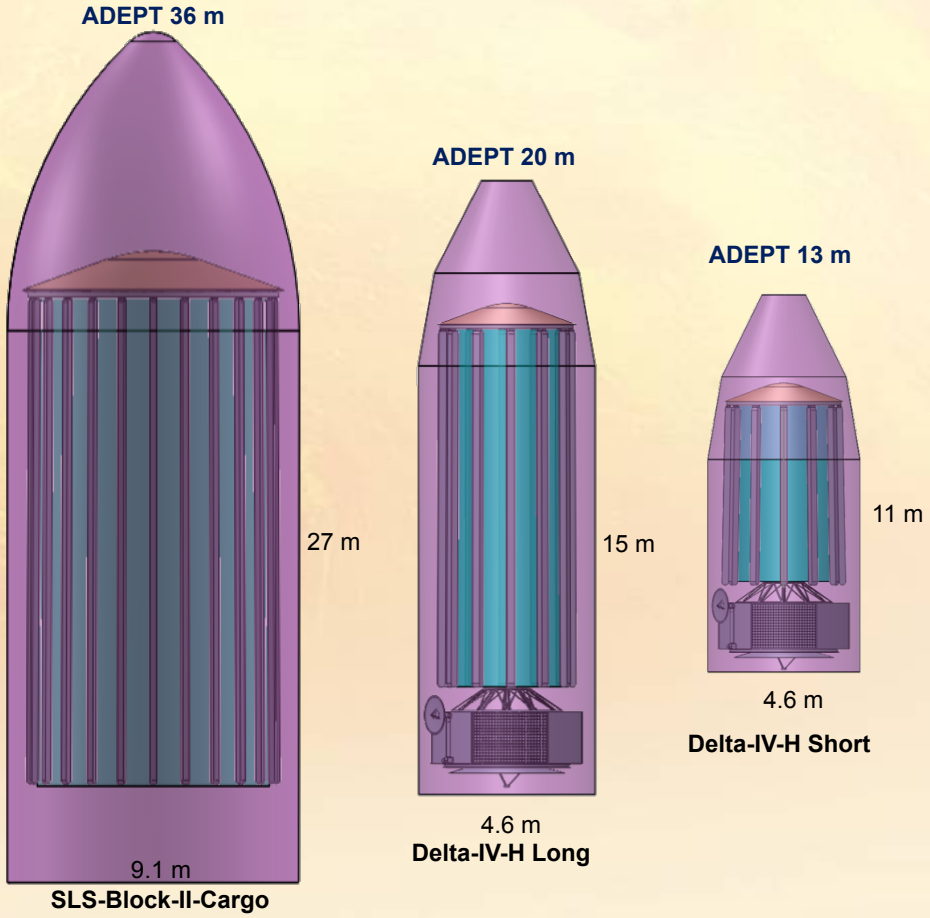


ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term

Scaling ADEPT for Mars Large Payload Missions

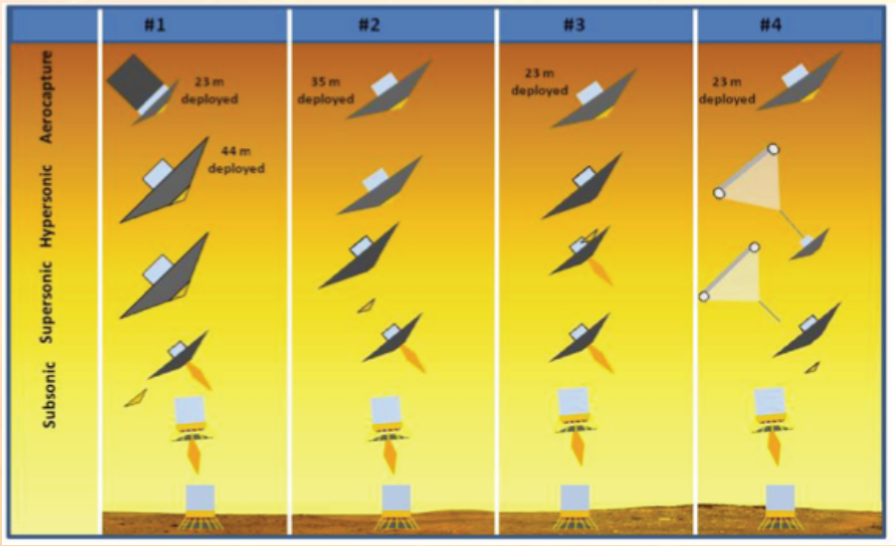
- **Road-Mapping and Systems Analysis Assessments are beginning to Plan EDL Development Path for Future Human Mars Exploration**

LV Static Payload Envelope – Maximum (Theoretical) ADEPT Size

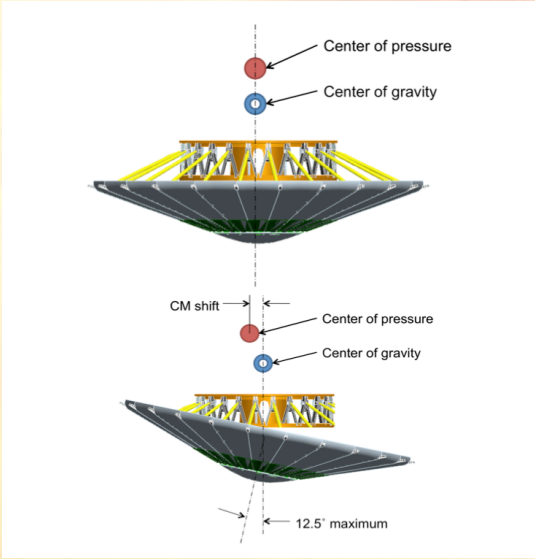


Considerations for Mars 2026 Sub-Scale Demo

Potential Low – β EDL Architectures



ADEPT generates lift with Gimballed Payload

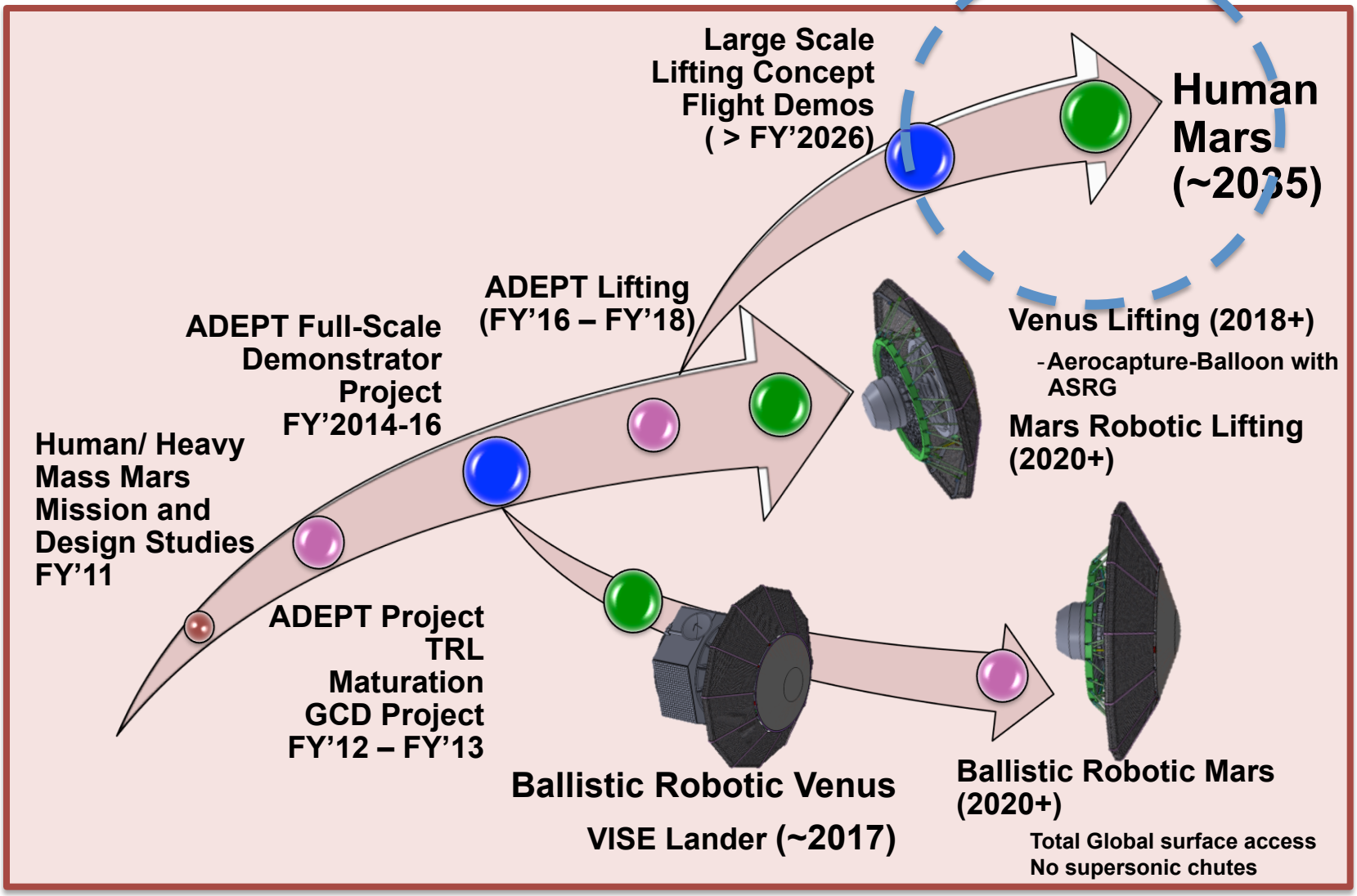


- **Demonstration Challenges for Sub-Scale Precursor Mission**
  - Performs aerocapture and subsequent entry from orbit
  - Accommodation of SRP (assumed for terminal descent)
  - ADEPT Aeroshell transforms to landing system during terminal descent

ADEPT considered a potential EDL implementation path for HEOMD Mars Missions

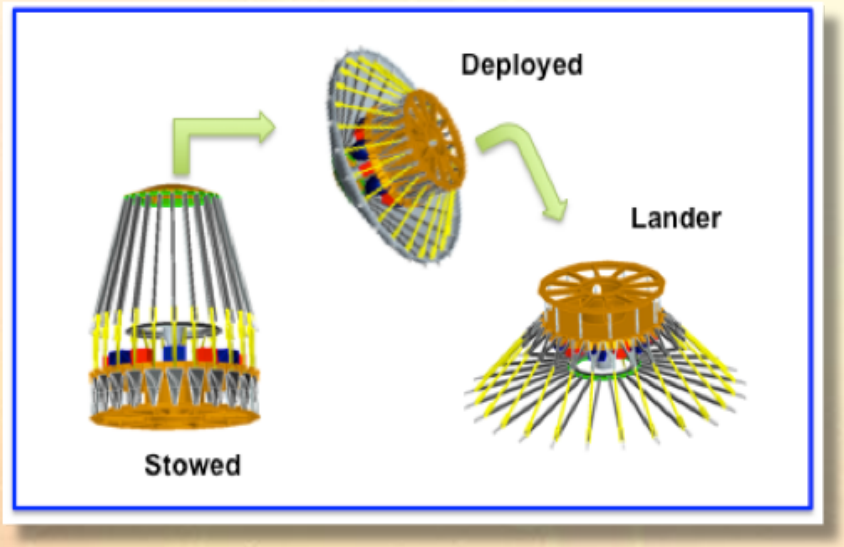
- Project will support Tech Development Road Mapping activities

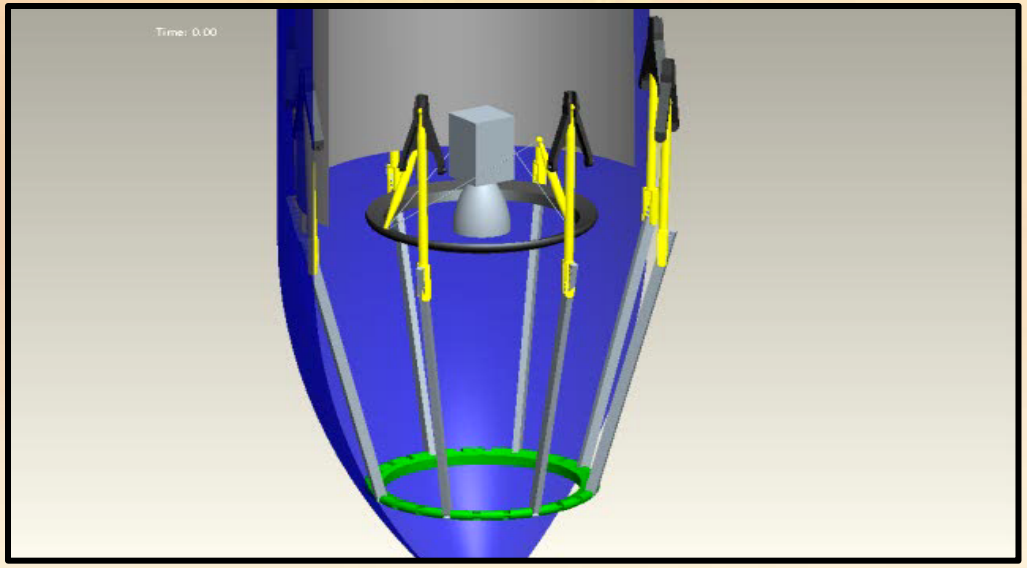
ADEPT Technology Maturation and Mission Infusion Timeline



ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term

ADEPT Scaled-Up (Way Up!) for Human Mars Missions





- Ribs, struts and and mechanisms allow deployment and gimballing of the frontal surface for lift vectoring during aerocapture, entry and descent.
- During landing, an invert maneuver allows the Aeroshell to be a landing attenuation system.
- Analysis, design, testing as well as mission design have been performed to prove viability of the mass competitive concept (Venkatapathy et al, AIAA 2011-2068)

Conclusion

- Low Ballistic Coefficient ADEPT Architecture:
  - Concept developed to address the grand EDL challenges of Human Mars mission
  - A simpler, non-lifting, ballistic entry architecture for large mass Mars landers (2+ mT)
    - Achieves subsonic parachute deployment at higher altitude compared to rigid aeroshell without lifting entry nor supersonic parachute
  - Candidate EDL architecture for Potential Mars 2026 Demonstrator mission
- STMD GCD is continuing investing in ADEPT Technology Maturation Project